WHITE OAK RIVER IMPOUNDMENT GAME LAND AQUATIC INVENTORY

by
Brian T. Watson and Aimee H. Fullerton

edited by
John M. Alderman

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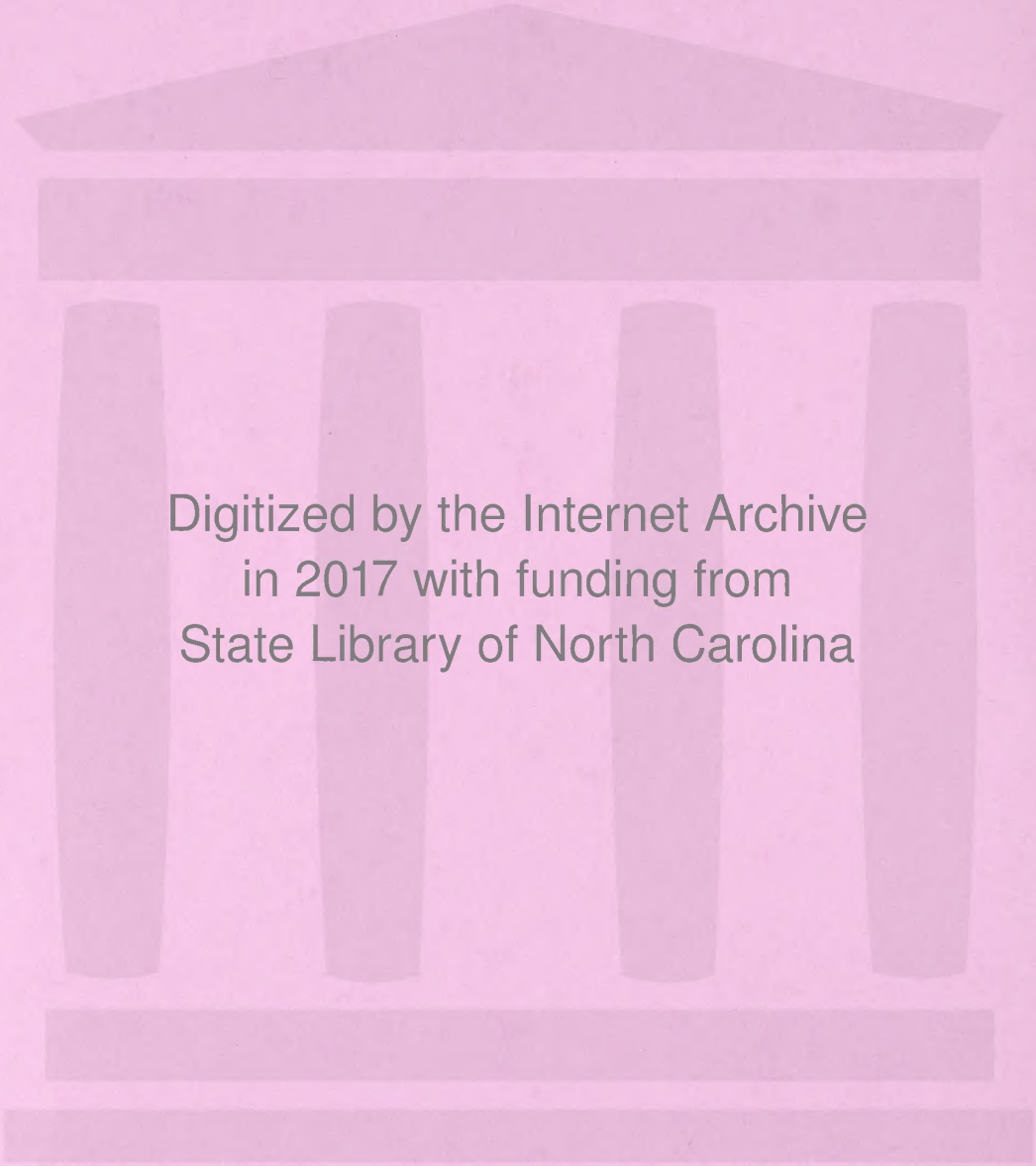

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WHITE OAK RIVER IMPOUNDMENT
GAME LAND AQUATIC INVENTORY

Introduction

White Oak River Impoundment Game Land is located in Onslow County, North Carolina, approximately 20 km east of Jacksonville and just south and west of the Croatan National Forest. The 100-acre tract of land lies within the White Oak River Basin, which encompasses 1,264 square miles of land in parts of Carteret, Jones, and Onslow counties. Most of the surface water in this basin is saltwater and, with only 277 miles of freshwater streams, this basin has the second lowest number of freshwater stream miles in North Carolina. The river is habitat for many endangered or threatened coastal species, including the Leatherback turtle and the Croatan crayfish. Its waters also are home for alligators and many delicious seafood favorites including shrimp, clams, oysters, and crabs. Unique for a coastal river, the banks of the White Oak are lined with steep cliffs, which are remnants of ancient ocean dunes. Given the small size of the river basin, the major waterways associated with the game land are the White Oak River and its headwater tributaries.

The North Carolina Wildlife Resources Commission (NCWRC) acquired the property in 1965 through a 25-year lease agreement with the landowner, Mr. William Percy Morton. At that time, approximately 100 acres of marshland were granted to the NCWRC for wildlife-related purposes. Later that year, a 100-acre waterfowl impoundment was constructed on the property through a cooperative agreement with the Onslow County Health Department. Realizing that the lease was due to expire in 1990, Mr. Morton expressed an interest in selling the property to the state. This process was initiated and approved in 1987. Over the years, the White Oak River Impoundment Game Land has become a popular area for waterfowl enthusiasts. Additional interests in the game land have been expressed as well, such as raising shrimp and clams. However, these activities would impact waterfowl habitat by altering current management of water levels. Since the game land has become a popular and important part of the NCWRC's waterfowl management program, requests for activities such as these have been denied.

Land use impact in the areas surrounding White Oak River Impoundment Game Land appears to be limited given its location and the amount of undisturbed area. A visual survey of the area reveals scattered localities of active crop and pasture lands, with some logging activity. Overall, the area adjacent to the game land is relatively undeveloped rendering urbanization impacts negligible.

The objective of this project was to survey the White Oak River Impoundment Game Land for aquatic species, including freshwater mussels, sphaeriid clams, aquatic snails, crayfishes, and fishes. Our goals were to determine species presence, distribution, relative abundance, and relative health. The inventory primarily focused on waterways associated with the White Oak River Impoundment Game Land within Onslow, Carteret, and Jones counties, North Carolina. Only a small area of the impoundment was surveyed due to the salinity levels and dominance by brackish water species. Figure 1 and Table 1 detail the localities of all sites surveyed. The following sections provide results of the aquatic inventory for each of the taxa mentioned above. For purposes of this report, *Corbicula fluminea* (Asian clam) was grouped with the sphaeriid

clams even though the 2 taxa belong to different families. It also should be noted that any plus or minus symbols listed after road numbers in the following tables represent whether we surveyed downstream or upstream, respectively.

Acknowledgements

We would like to thank the following people, without whose assistance this project would not have been possible: John M. Alderman (NCWRC) for reviewing and editing the report; Phillip A. Stone (NCWRC) for providing access point information regarding the game land; Dr. John E. Cooper, Dr. Arthur E. Bogan, and Dr. Wayne C. Starnes, Gabriela M. Hogue, Dr. Morgan E. Raney, and Lynn Fullbright from the NC State Museum of Natural Sciences for providing assistance with identifications of crayfishes, mollusks, and fishes, respectively; Dr. Gerald L. Mackie from the University of Guelph, Ontario, Canada, for providing assistance with sphaeriid identifications. We also would like to thank the landowners and residents of Carteret, Jones, and Onslow counties, North Carolina, who allowed us to work on their property and showed an interest in their local natural history.

Prepared by: Brian T. Watson, Nongame Wildlife Biologist
Aimee H. Fullerton, Nongame Wildlife Biologist
Nongame and Endangered Wildlife Program

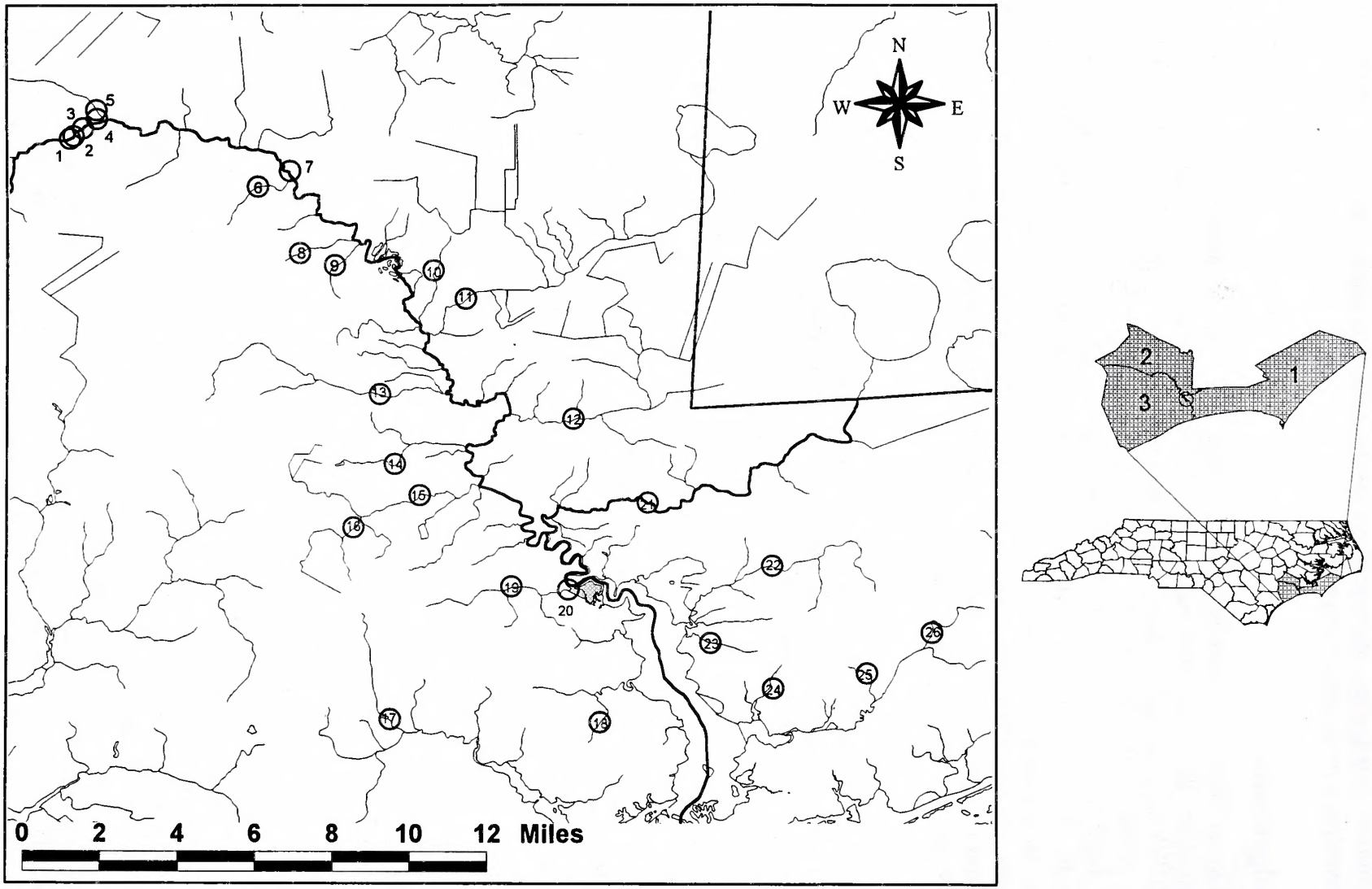

Figure 1. Map of sites surveyed during the aquatic inventory of White Oak River Impoundment Game Land in Carteret (1), Jones (2), and Onslow (3) counties, North Carolina, 2000. The location of the game land within the counties, and the location of the counties within the state of North Carolina, are shown to the right.

Table 1. Map numbers, corresponding sites surveyed, and survey effort (person-hours/ electroshock seconds) for the White Oak River Impoundment Game Land aquatic inventory (see Figure 1).

Map #	Site Number(s)	Survey Effort
1	001018.1btw	1.5
2	001018.2btw	1.5
3	001018.3btw	1.0
4	001018.4btw	incidental
5	000531.1btw	1.0
6	000531.2btw	1.5
7	001023.1btw	3.0
8	000531.3btw	incidental
9	000531.4btw	0.75
10	000531.5btw	0.75/277
11	000531.6btw	1.0
12	000601.1btw	1.5/310
13	000510.5btw	1.5/309
14	000511.1btw	1.25/279
15	000511.2btw	0.5/214
16	000511.3btw	1.0/193
17	000511.4btw	1.0/296
18	000518.1btw	1.5/324
19	000511.5btw	1.5/229
20	001017.1btw	incidental
21	000601.2btw	1.25/334
22	000601.4btw	0.75/415
23	000601.3btw	1.0/158
24	000518.4btw	0.5
25	000518.2btw	0.33
26	000518.3btw	1.25/332

FRESHWATER MUSSELS AND SPHAERIID CLAMS

Brian T. Watson, Nongame Wildlife Biologist
Nongame and Endangered Wildlife Program
Division of Wildlife Management
NC Wildlife Resources Commission

Introduction

The freshwater mussel fauna (Bivalvia: Unionoidea), also referred to as unionids or pearly mussels, is an intriguing, diverse, and important group of mollusks. Unionids are often prominent in macrobenthic aquatic communities where, for the most part, they are sedentary filter-feeders. Because unionids consume a major portion of the suspended particulate matter, they provide a number of important roles in aquatic ecosystems, two of which include serving as biological filters and water quality indicators. Mussels also serve as an important dietary component to a number of animals, and economically, their shells provide the nuclei used in the profitable cultured pearl industry (Theil and Fritz 1993). While not as much information has been ascertained for the sphaeriid clams (Bivalvia: Sphaeriidae), also called pea, pill, nut, or fingernail clams, they too serve an important role in aquatic ecosystems as filter-feeders. As part of the inventory of aquatic animals associated with the state-owned White Oak River Impoundment Game Land, we conducted field surveys of freshwater mussels and sphaeriid clams found in waterways occurring in and around the game land to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

The life cycle of freshwater mussels is an intricate process that is fairly unique when compared to that of other organisms. Spawning begins with the release of sperm from the excurrent aperture of mature males. As the sperm passively drift with the currents, they enter females through their incurrent aperture. Within sexually mature females, fertilization takes place in the suprabranchial cavity, and the resulting embryos are retained in the marsupial gills until they develop into parasitic larvae called glochidia. Glochidia are obligate parasites and must attach to suitable host fishes. Ortmann (1911) described 2 general reproductive modes for unionids based on the length of time that glochidia are retained in the gills of the female. Bradytictic, or long-term brooders, typically spawn in late summer, brood young over the winter, and release mature glochidia during the following spring or early summer. Tachytictic, or short-term brooders, typically spawn in the spring and release mature glochidia sometime during that summer.

Once maturity is reached, the glochidia are released into the water column through the female's excurrent aperture, from specialized gill pores, or by rupture of the ventral portion of the gill (McMahon 1991). Once released by the female, glochidia passively drift with the currents until they attach to suitable host fishes or die. Mechanisms promoting glochidia-fish contact include respiratory, feeding, and spawning activities of fishes, as well as specialized morphologies and behaviors of particular mussel species (Kraemer 1970, Dartnall and Walkey 1979, Zale and Neves 1982). Attachment occurs on the gills, fins, or scales, depending on the mussel subfamily, and is followed by encystment and metamorphosis into juveniles. Metamorphosis generally occurs over a period of 1-3 weeks (Neves 1991) but can last for a few months (Zale and Neves

1982). Once metamorphosis is complete, the juvenile mussel drops from the host fish, settles into the surrounding substrata, and, if conditions are suitable, grows until sexual maturity occurs. Then, the reproductive cycle is repeated. During a mussel's reproductive years, growth rates are reduced since significant energy and nutrients are required to produce young.

Unlike unionids, sphaeriid clams are ovoviviparous, self-fertilizing hermaphrodites. All species brood developing embryos in specialized chambers where maternal nutrients are supplied to the embryos. After maturity is reached, the once developing embryos are released into the water column as miniature adults. Due to their relatively large size as mature embryos, compared with other freshwater bivalves (Mackie 1984), most juvenile sphaeriids disperse between drainage systems by clamping their shells onto things such as aquatic insects (McMahon 1991), feathers of waterfowl (Burky 1983), or the limbs of salamanders (Davis and Gilhen 1982) rather than dispersal by water currents. Given highly variable reproductive success rates, sphaeriids typically have 1-3 reproductive efforts per year (McMahon 1991). *Corbicula fluminea* reproduces in much the same manner as sphaeriid clams but tends to use the water currents as its primary means of dispersal (Williams and McMahon 1986). Most populations of the Asian clam have 2 reproductive efforts per year, one in the spring and the second in the late summer (McMahon 1983a).

Habitat Requirements

Freshwater mussels occur in a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with unionids generally being most successful and prevalent in stable, coarse sand, or sand-gravel mixtures (Way et al. 1990a). Water velocity also plays a critical role in the distribution, diversity, and abundance of mussel populations. Unionids tend to thrive in conditions where water velocities are low enough to allow for substrata stability, but high enough to prevent excessive siltation (Way et al. 1990a). Water velocity also affects the amount of nutrients carried to the filter-feeding organisms. Chemical parameters such as pH and calcium concentrations can influence the distributions of mussel populations as well. The majority of species prefer alkaline water with a pH above 7.0, but unionids can grow and reproduce over a pH range of 5.6 - 8.3 and can tolerate acidic conditions as low as 4.7 (Okland and Kuiper 1982). Typically, habitats of low pH also have low calcium concentrations. Low calcium concentrations can lead to poor growth and shell dissolution in some individuals, especially if the shell is worn (Kat 1982). Given that growth and dissolution rates are affected by many factors other than pH and calcium concentrations, the minimum tolerable values can vary significantly among habitats. Another important factor to mention in the viability of freshwater mussel populations is the need for suitable host fishes. If the proper host fish is not present for a particular mussel species at any given location, then eventually this species will become extirpated from the site regardless of the habitat conditions.

Sphaeriid clams and Asian clams are generally more tolerant than unionids of what we consider to be harsh conditions. Unlike many unionids, the diversity and abundance of some *Pisidium* and *Sphaerium* species are inversely correlated with substrata size (Kilgour and Mackie 1988), which may be associated with sediment organic feeding mechanisms. *Corbicula fluminea* has a much broader substrata range, and has been seen to successfully colonize habitat consisting of bare rock outcrops to habitat with high silt loads. The highest abundances of *C. fluminea* in

North Carolina are often associated with sandy disturbed habitats or with lotic habitats below dams (J.M. Alderman, NC Wildlife Resources Commission, pers. comm.). Sphaeriids have the ability to colonize ponds and lakes where the depth is greater, the flow is negligible, and the sediment and organic loads are high. Again, this may be associated with feeding mechanisms in sphaeriid clams. Chemical parameters such as pH and calcium concentration regulate sphaeriid clams and *C. fluminea* populations in much the same manner that they affect unionid populations.

Taxonomy, Distributions, and Statuses

Freshwater mussels are represented worldwide, with North America containing the largest collection - 297 currently recognized species and subspecies (Williams et al 1993). While unionids are distributed across the entire continent, the greatest diversity lies within the southeastern United States (Neves et al. 1997). North Carolina's share of this diversity is impressive. Once our taxonomic understanding is more complete, approximately 70 species are expected to occur in our state. A significant amount of literature describing site locations for unionids across North America has led to a more refined understanding of the distribution and taxonomy of this fauna.

Of the 297 recognized taxa of freshwater mussels in North America, Williams et al. (1993) recommended that 213 (72%) be considered endangered, threatened, or of special concern. Nearly half of North Carolina's freshwater mussel species are state listed as endangered, threatened, or special concern, and approximately 30% have undetermined statuses (J.M. Alderman, NCWRC, pers. comm.).

Sphaeriid clams are widely distributed and are represented in North America by approximately 38 species (Burch 1975, Turgeon et al. 1998). In North Carolina, there are approximately 13 species (Adams 1990). No species is currently listed at this time.

Anthropogenic effects, such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration are negatively affecting these taxa. With the introduction of exotic species, such as *C. fluminea*, and the impending introduction of *Dreissena polymorpha* (zebra mussel), the situation continues to worsen. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The freshwater mussel and sphaeriid clam survey of White Oak River Impoundment Game Land was conducted during the spring and fall of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and the White Oak River was surveyed via canoe. For clear and tannic shallow streams, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters. For waterways that were mostly swampy, and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater mussels were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). In areas where water clarity allowed, freshwater mussels were collected by viewing the substrata through the water surface with the naked eye. These areas also were surveyed with a view scope depending on the depth of the water. In areas that were turbid or tannic, freshwater mussels were collected by tactilely surveying suitable habitat. Freshwater mussels also were collected from sites by sieving the substrata through a 1/8-inch mesh dip net. The tactile search was the most prevalent search technique utilized due to the conditions of the waterways associated with the game land. If a mussel was located, we typically performed a tactile timed search in the area to determine an approximate abundance at each site. We also noted the type of substrata in which mussel populations colonized to determine if there were any species-specific preferences. Live mussels were identified to species, measured to the nearest mm for length using a Vernier caliper, and returned unharmed to the appropriate habitat. Some individuals were preserved in 95% ethanol and kept for curation. Shells were collected and identified to species, measured for length (mm), and kept for curation. All common and scientific nomenclature follows Turgeon et al. (1998). John Alderman (NCWRC) verified some of the species identifications.

Sphaeriid clams were collected using a variety of methods, including dip netting, and tactile and visual searches. The most prevalent method used was dip netting. This involved running a 1/8-inch mesh dip net through vegetation and the substrata to search for the clams. Most specimens collected were preserved in 70% ethanol and identified according to Burch (1975). Specimens also were sent to Dr. Gerald L. Mackie, University of Guelph, Ontario, Canada, for identification confirmation. All common and scientific nomenclature follows Turgeon et al. (1998).

Results

Over 8 days from 10 May to 23 October 2000, 26 sites were inventoried and freshwater mussels were collected or observed at only 6 sites (Figure 2a and Table 2a). Three species were collected during the inventory: *Elliptio complanata* (eastern elliptio), *E. icterina* (variable spike), and lanceolate *Elliptio*. Statistics on valve lengths of each species collected can be seen in Table 2b. Reproduction was rare as it was observed for *Elliptio complanata* by a single shell.

Elliptio complanata (eastern elliptio) was the most common mussel species found during the White Oak River Impoundment Game Land aquatic inventory. A total of 66 live individuals and 11 shells were collected from all 6 sites in which mussels were found. Individuals typically were collected in substrata comprised of sand with minimal silt and detritus. Individuals also could be found along clay banks where silt and detritus were more prominent. Time-search abundance estimates of the eastern elliptio were highly variable, ranging from < 1 mussel per hour to approximately 100 mussels per hour. Four of the sites averaged 1 mussel or less per hour, while the other 2 sites (7 and 13, see Figure 1) averaged over 50 mussels per hour.

Elliptio icterina (variable spike) and lanceolate *Elliptio* were both collected from only a single site (7) in the White Oak River. A total of 5 live individuals and 1 shell of the variable spike and 1 live lanceolate *Elliptio* specimen were collected from this site. Individuals of both species were found in sand and silt substrata with a run-like flow regime. The time-search abundance estimates of *E. icterina* and lanceolate *Elliptio* were approximately 3 and < 1, respectively.

Over the same time period and at 25 localities (site 4 was surveyed primarily for mussels), sphaeriids were collected at 9 sites (Figure 2b and Table 2c). Five species were collected during the inventory: *Pisidium casertanum* (ubiquitous peaclam), *Pisidium adamsi* (Adam peaclam), *Pisidium compressum* (ridged-beak peaclam), *Musculium partumeium* (swamp fingernailclam), and *Sphaerium simile* (grooved fingernailclam). No species dominated the area, but at least 1 *Pisidium* species was collected at each site that we surveyed. *Corbicula fluminea* was not observed. Overall, the abundance of each species was rare and reproduction was minimal.

In addition to the unionids and sphaeriids, a few species of brackish water organisms were collected. These species included *Polymesoda caroliniana* (Carolina marsh clam), *Brachidontes exustus* (scorched mussel), and a barnacle (most likely *Balanus* sp.). All these species were collected from marsh areas on the game land property (site 20), indicating the unlikelihood that freshwater bivalves reside on the tract of land.

Discussion

The overall diversity of the freshwater mussel fauna in White Oak River Impoundment Game Land and its associated waterways is low. Further comparisons to other waterways within the White Oak River Basin are hampered due to a lack of recent surveys. Likewise, Johnson (1970) doesn't identify a particular species list for this small river basin. A search of the NCWRC Nongame database did indicate that *Elliptio complanata* and lanceolate *Elliptio* were collected from the White Oak River during September of 1993. In addition, specimens identified as *Elliptio* spp. were collected from the White Oak River and a number of its tributaries at this time. A survey of the Croatan National Forest (Alderman et al. 1994) indicated that at least 6 mussel species are present in the area, three of which were represented in our survey. However, the Croatan National Forest survey also included portions of the lower Neuse River Basin, so comparisons to this survey are limited. Considering these data, our survey appears to be indicative of the mussel fauna of the area.

Current distribution patterns and ranges of the sphaeriid fauna are much less understood than those for the freshwater mussel fauna. The location of 5 sphaeriid species at 9 sites is relatively high when compared to other aquatic inventories conducted by the authors within North Carolina. The Croatan National Forest Survey (Alderman et al. 1994) resulted in the collection of only 1 sphaeriid species in the White Oak River Basin, which was represented in our survey as well. It appears from the game land survey that the area has a high diversity of sphaeriid clams, but their overall distributions and abundances are poor.

The water body types that we encountered during our survey were relatively homogeneous: mostly tannic and swamp like. Given the limited range of available habitat types, it is not atypical to discover a lack of freshwater mussel diversity since they are typically more successful in areas with diverse habitat types (see Background, Habitat Requirements). Additionally, the lack of freshwater streams in the White Oak River Basin has excluded many waterways as potential habitat for unionids. Given these factors, it was surprising to find a relatively high number of sphaeriid species. However, the low freshwater stream mileage in the river basin may have contributed significantly to their limited distributions. It also is likely that the influence of geomorphologic and topographic factors have significantly affected the current unionid and

sphaeriid fauna. Major landscape scale factors such as these are known to influence and impact the distributions and abundances of organisms over time, and it is possible that the area we surveyed has a naturally low presence of freshwater mussels. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. Effects from urbanization were minimal since most of the river basin is rural.

The collection of *Sphaerium simile* in the White Oak River is significant, as it appears this is the first record of the fingernail clam in North Carolina (G.L. Mackie, University of Guelph, pers. comm.). The historical distribution of this species is described as extending from southern Canada from New Brunswick to northern and central British Columbia, south to Virginia, Iowa, and Wyoming (Burch 1975). However, it is possible that this species was collected from the same site in 1992 during the Croatan National Forest inventory (Alderman et al. 1994). McGrath tentatively identified some pea clam specimens from the White Oak River as *Sphaerium simile*. However, it is not known if these specimens were verified as such since G.L. Mackie has no records of these specimens, and it was indicated in the report that all sphaeriid specimens were being sent to him for identification verification.

While no threatened or endangered bivalve species was collected during the survey of White Oak River Impoundment Game Land, continual research and status surveys are needed to determine the present status of each species. *Musculium partumeium* and *Pisidium adamsi* are currently considered species of undetermined status (Adams 1990), but recent surveys by the authors have shown these species to be common across the Coastal Plain and parts of the Piedmont. Current land management practices, including agriculture and urbanization, are having an effect on the bivalve fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

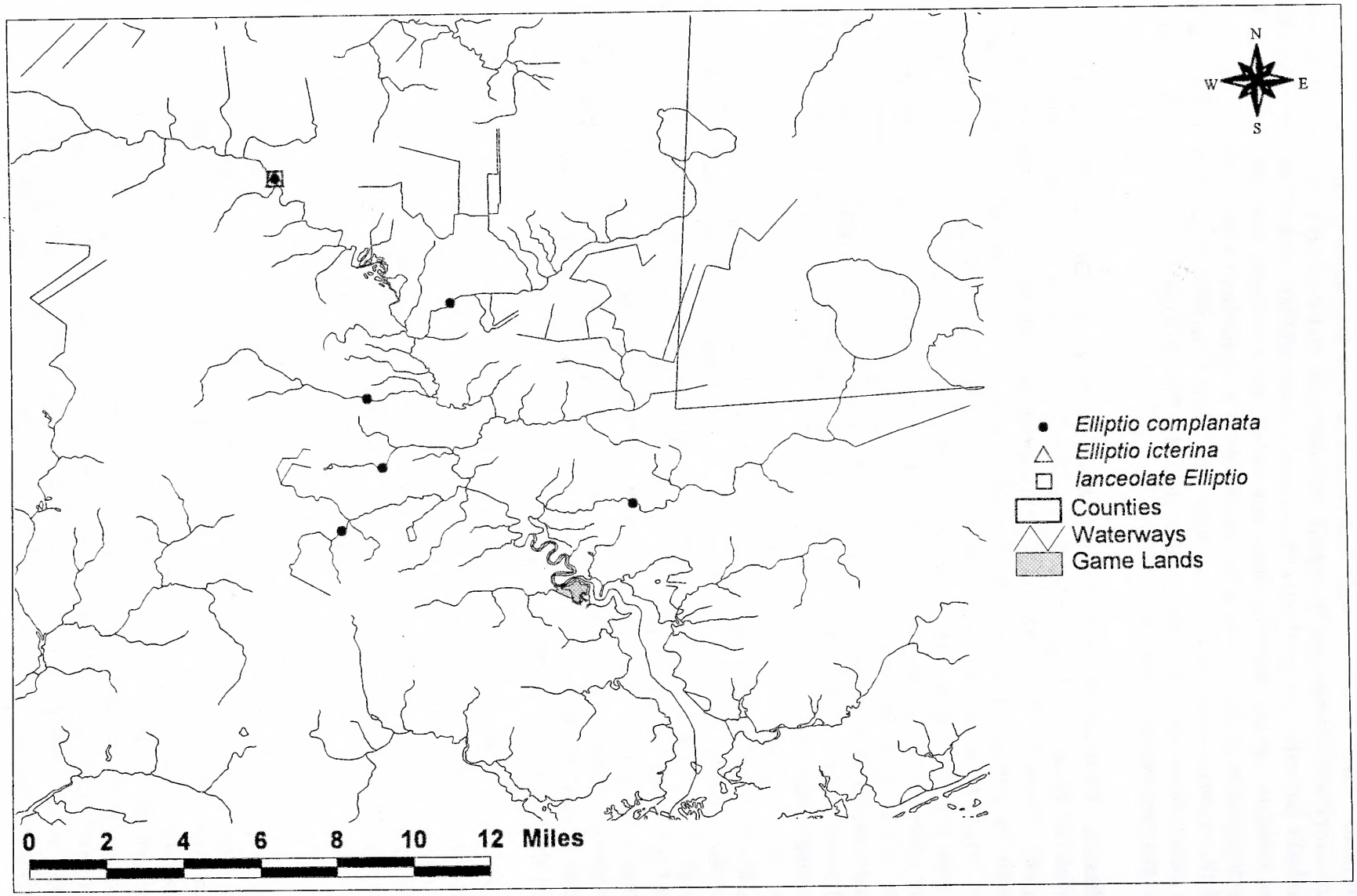

Figure 2a. Map of sites indicating where each species of freshwater mussel was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

Table 2a. Freshwater mussel species found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Elliptio complanata							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	common	B.T. Watson, J.M. Alderman
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson, J.M. Alderman
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson, J.M. Alderman
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	present	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	uncommon	B.T. Watson, J.M. Alderman
Elliptio icterina							
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	J.M. Alderman, B.T. Watson
lanceolate *Elliptio*							
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	rare	B.T. Watson

Table 2b. Statistics on valve lengths of live freshwater mussels and shells found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Elliptio complanata	Avg	Std	Min	Max
live (66 records)	69.6	12.5	45.0	101.0
shell (11 records)	64.8	14.6	22.0	75.0
Species Total (77 records)	68.9	12.8	22.0	101.0
Elliptio icterina	Avg	Std	Min	Max
live (5 records)	66.0	3.9	62.0	72.0
shell (1 record)	62.0		62.0	62.0
Species Total (6 records)	65.3	3.9	62.0	72.0
lanceolate *Elliptio*	Avg	Std	Min	Max
live (1 record)	56.0		56.0	56.0
Species Total (1 record)	56.0		56.0	56.0

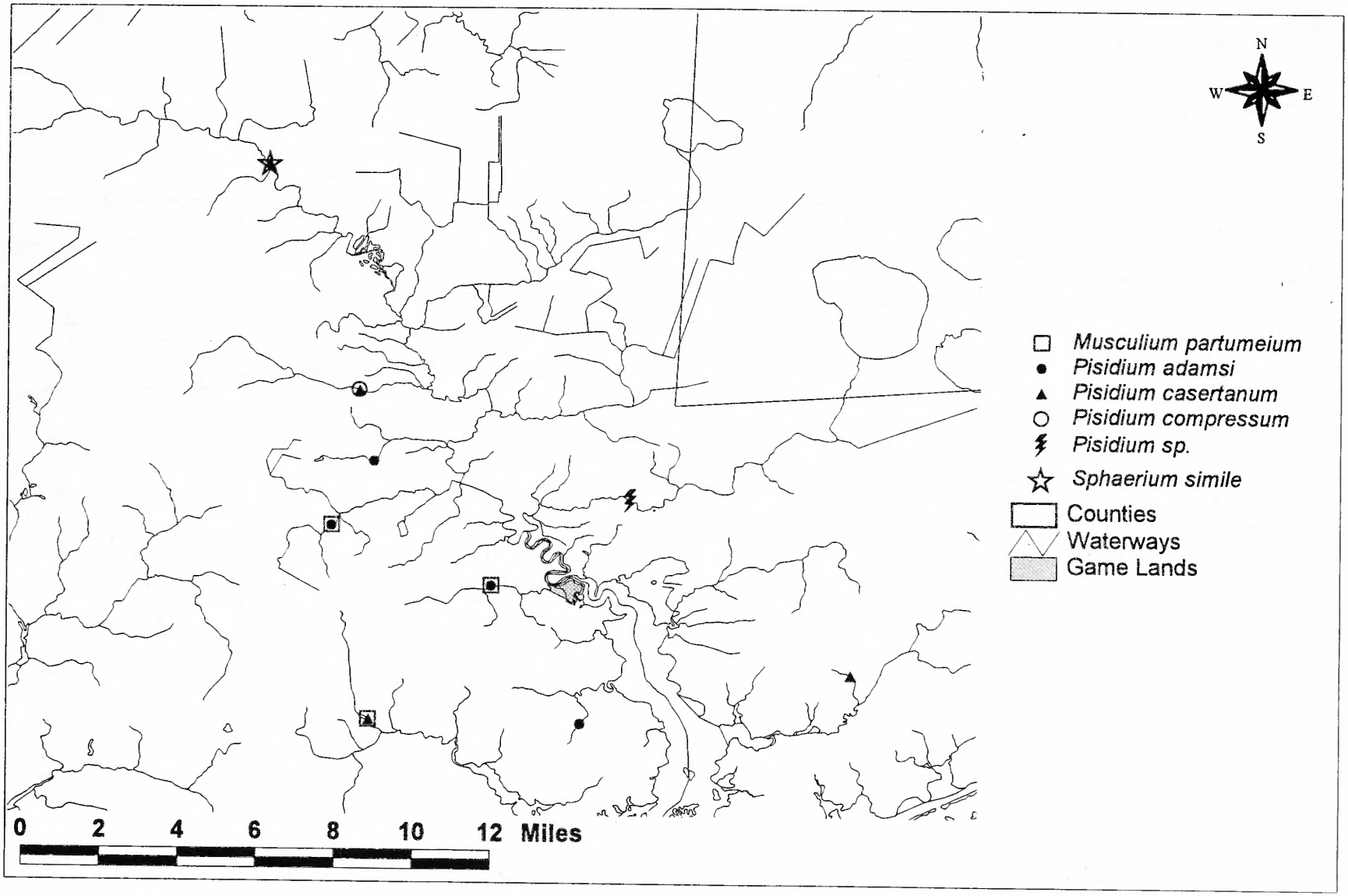

Figure 2b. Map of sites indicating where each species of sphaeriid clam was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

Table 2c. Sphaeriid clam species found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Musculium partumeium							
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson, G.L. Mackie
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
Pisidium adamsi							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	G.L. Mackie
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	G.L. Mackie
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	G.L. Mackie
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	patchy uncommon	G.L. Mackie
Pisidium casertanum							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson, G.L. Mackie
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson, G.L. Mackie
000518.2btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 206 -	rare	B.T. Watson, G.L. Mackie
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson, G.L. Mackie
Pisidium compressum							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	G.L. Mackie
***Pisidium* sp.**							
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	present	B.T. Watson
Sphaerium simile							
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	G.L. Mackie, B.T. Watson

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AQUATIC SNAILS

Brian T. Watson, Nongame Wildlife Biologist
Nongame and Endangered Wildlife Program
Division of Wildlife Management
NC Wildlife Resources Commission

Introduction

Freshwater snails (Mollusca: Gastropoda) are among the most ubiquitous organisms of shallow littoral zones in lakes and streams. Due to their behavior, widespread distribution, and commonly high abundance, snails serve a number of important roles in aquatic ecosystems. These include driving predator-prey interactions (Vermeij and Covich 1978, Lodge et al. 1987), serving as a dietary component to fish and wildlife, acting as water quality indicators, and most importantly, grazing on nuisance algae and detritus. However, freshwater snails are often overlooked in part due to their small size, perceived lack of charisma, cryptic habits, and the lack of readily available comprehensive guides for identification. As part of the inventory of aquatic animals associated with the state-owned White Oak River Impoundment Game Land, we conducted field surveys of aquatic snails found in waterways occurring in and around the game land to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

Much information about the reproductive cycles of freshwater snails has been ascertained due to the ease of laboratory rearing. From this information, 2 typical categories have been developed in which snails can be placed reproductively (Russell-Hunter 1978, Calow 1978). The first category includes annual adults that reproduce in the spring and die (semelparous). Most pulmonates (lung breathing), which are oviparous hermaphrodites, belong to this group including the genera *Lymnaea* and *Physa*. The second category includes perennial adults that reproduce in both spring and late summer. Most prosobranchs (gill breathing), which are dioecious and can be oviparous or ovoviviparous, belong to this group. These species are iteroparous and often live and reproduce for 4-5 years. Prosobranchs also are often sexually dimorphic, with females living longer than males (Brown et al. 1989).

Habitat and Food Requirements

Freshwater snails occupy a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with well-documented substratum selection (Brown 1991). In general, silty habitats with slow-moving currents are colonized predominately by pulmonates or detritivorous prosobranchs, whereas limpets or prosobranch grazers colonize fast-current localities (Harman 1972). Many biotic and abiotic factors regulate the distribution of freshwater snails, with water hardness and pH considered to be the major determinants (Macan 1950, Pip 1986). However, it has been suggested that physiochemical factors such as calcium concentrations may only act to limit successful invasion of habitats with extreme levels of these factors (Lodge et al. 1987). Other factors such as dispersal ability and adequate substrata may play a more prominent role in snail distribution.

Freshwater snails are predominantly herbivores or detritivores, although they can ingest carrion (Bovbjerg 1968) or passively consume small invertebrates associated with periphyton (Cuker 1983a). Apparently, they prefer periphyton because it is easier to scrape than macrophytes, and it contains higher concentrations of nitrogen and other limiting nutrients (Russell-Hunter 1978, Aldridge 1983). Algae and diatoms also are prominent sources of nutrients for freshwater snails (Lodge 1986). While macrophytes are not the preferred source of nutrients for most freshwater snails, significant consumption can occur if snail densities reach high levels (Sheldon 1987).

Taxonomy, Distribution, and Statuses

Freshwater snails are divided into 2 groups – prosobranchs and pulmonates. Prosobranch snails are gill breathing and have a calcareous plate called an operculum that seals the aperture when the snail withdraws into its shell. Pulmonate snails are lung breathing and lack an operculum. Of the approximately 500 species recognized in North America, there are 49 genera and 349 species of prosobranch snails and 29 genera and 150 species of pulmonate snails (Burch 1982). While snails are widespread across the continent, they have reached their greatest abundance and diversity within the streams of the southeastern United States (Brown 1991). In North Carolina, there are approximately 52 species representing 10 families (Bogan 1997). Since very little work has been done to monitor freshwater snail populations, the current status of many species within North Carolina is undetermined. It is unknown as to the magnitude of impact that anthropogenic effects such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration have had on the state's snail fauna. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The aquatic snail survey of White Oak River Impoundment Game Land was conducted during the spring and fall of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and the White Oak River was surveyed via canoe. For clear and tannic shallow streams, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters. For waterways that were mostly swampy, and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater snails were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common methods used to sample the snail fauna were visual searches and dip netting. The visual search basically involved examining rocky substrata, woody debris, vegetation, cans and bottles, and other items that snails might colonize. Dip netting involved running a 1/8-inch mesh dip net through vegetation and the substrata to collect snails. Other techniques used to collect snails included tactile searches and the use of a viewscope. Habitat preference, relative abundance, and recent reproduction for snail species were noted at each site. Snails were preserved in 70% ethanol and identified according to Burch (1989) and Basch (1963). Scientific names are according to Turgeon et al. (1998). Dr. Arthur E. Bogan, curator of aquatic invertebrates at the NC State

Museum of Natural Sciences, verified some of the species identifications. Not all snails collected were preserved for obvious conservation and ethical reasons.

Results

Over 8 days from 10 May to 23 October 2000, 25 sites were inventoried (site 4 was surveyed primarily for mussels) and aquatic snails were collected or observed at 22 localities (Figures 3a-c). At least 9 species representing 6 families were documented during the White Oak River Impoundment Game Land survey (Tables 3a and 3b). Due to the likely misidentification of *Planorbella trivolvis* as *Helisoma anceps* (see Discussion), we have listed these collections as both species. The relative abundance of each species varied, but by far the most abundant and widespread species was *Ferrissia* sp., with the ancylid residing at 15 sites (Figure 3c). Due to species level variation and the uncertainty of positively discerning *Ferrissia* specimens, all specimens of this genus were identified as *Ferrissia* sp. *Pseudosuccinea columella* and *Micromenetus dilatatus* were the next most abundant gastropods, residing at 9 and 8 sites, respectively. The remaining snail species were represented over a smaller number of sites, ranging from 2-6. Regardless of the number of sites from which a particular species was collected, abundances were typically rare to uncommon over the entire surveyed range. Recent reproduction was seen at a number of sites for all the snail species collected during the survey except the rams-horn. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and *Amnicola limosa*), it was difficult to confirm whether these were adults or juveniles and typically reproduction was not recorded.

Ferrissia sp., *Laevapex fuscus* (dusky ancylid), and *Micromenetus dilatatus* (bugle sprite) were typically found in areas with slow to moderate flow on aquatic vegetation and woody debris. These species also were found on cans and bottles, with the ancylids being especially common on these items.

Physella sp. (physa snail), *Campeloma decisum* (pointed campeloma), *Pseudosuccinea columella* (mimic lymnaea), *Helisoma anceps/Planorbella trivolvis* (two-ridge/marsh rams-horn), and *Planorbella duryi* (Seminole rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the stream bank, behind sandbars, or wherever the conditions were swamp-like. *C. decisum* was found predominantly in sand and detritus, but occasionally an individual was found on the clay banks or on woody debris or vegetation. *Physella* sp. *and P. columella* typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks. The rams-horn(s) was typically associated with detritus and vegetation in stagnant and backwater areas.

Like most of the other species, *Amnicola limosa* (mud amnicola) was typically collected from areas with swamp-like or slow flow. Specimens tended to be common on woody debris but also were collected from detritus and vegetation.

In addition to freshwater gastropods, one species of brackish water snail was collected: *Melampus bidentatus* (eastern melampus or salt marsh snail). This species was collected from marsh areas on the game land property (site 20), indicating the unlikelihood that freshwater gastropods reside on the tract of land.

Discussion

Overall, the diversity and abundance of freshwater snails in the waterways associated with the White Oak River Impoundment Game Land appear to be moderate to high. The results reported here are typical of additional state-wide aquatic inventories conducted by the authors. In comparison to the survey of the Croatan National Forest (Alderman et al. 1994), our results are very similar, with our inventory resulting in a total of 9 gastropod species compared to 8. While the Croatan National Forest survey also included a portion of the lower Neuse River Basin, all of the species reported were collected from at least the White Oak River Basin. Thus, it appears that we captured a representative sample of the gastropod fauna associated with the White Oak River Impoundment Game Land. Further comparisons are limited due to a lack of recent surveys.

Some of the differences seen between the 2 surveys may have likely arisen form identification discrepancies. Given the wide spread distribution and small size of *Micromenetus dilatatus*, it is easy to field misidentify similar species as the bugle sprite. During the game land survey, we noted *M. dilatatus* at 8 sites. However, it is likely that at least some of these specimens were *Promenetus exacuous* since the species was noted in the Croatan National Forest aquatic survey (Alderman et al. 1994). Similarly, *Planorbella trivolvis* was noted by Alderman et al. (1994), while we originally field identified planorbid specimens from 2 sites as *Helisoma anceps*. Since specimens field identified as *H. anceps* during the proximal Neuse River Game Land aquatic inventory were later confirmed to be *P. trivolvis*, it is likely the specimens we collected, but did not preserve, were the marsh rams-horn as well. Similar discrepancies may have occurred with ancylid identifications, which is explained below.

Given the relative lack of diverse habitat types and flow regimes encountered, and the low number of freshwater stream miles in the river basin, it was unexpected that we would find a relatively healthy number of gastropod species. However, these factors may have been the primary dynamic contributing to their limited distribution and low abundance. It also is likely that the influence of geomorphologic and topographic factors have significantly affected the current gastropod fauna. Major landscape scale factors such as these are known to influence and impact the distribution and abundance of organisms over time. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. Effects from urbanization were minimal since most of the river basin is rural.

Taxonomic uncertainties within the freshwater snail fauna make the results here subject to revision. For example, the differentiation between *F. rivularis* and *F. fragilis* is difficult due to shell shape variation. Therefore, a common factor used to distinguish these species is the habitat they are collected in, with *F. rivularis* colonizing rivers and streams and *F. fragilis* inhabiting stagnant areas such as ditches, ponds, and backwater areas (Burch 1989). All of the limpets identified in this survey were assigned to *Ferrissia* sp., but it is likely that at least both species inhabit some of the sites that were surveyed, with *F. fragilis* more dominant in the region. Some of the *Ferrissia* sp. field identifications could also have been *Laevapex fuscus* given the difficulty in sometimes differentiating smaller specimens in the field. Likewise, many

uncertainties exist as to the taxonomy of *Physella* and hydrobiids without examination of soft parts (Burch 1989). Since we did not preserve the specimens for the examination of soft parts, we identified *Physella* specimens to genus only and the hydrobiid identifications are tenuous.

The collection of *Planorbella duryi* in the White Oak River Basin is significant, as it appears this is the first record of the gastropod in North Carolina (Bogan 1997). The historical distribution of this species is described as extending from northern to southern Florida (Burch 1989). It is believed this species was introduced through the aquaria trade (A.E. Bogan, NCSM, pers. comm.). On a past trip to a local aquarium shop, Bogan viewed specimens of the Seminole rams-horn on aquatic vegetation that had been shipped from Florida.

While no threatened or endangered gastropod species was collected during the survey of White Oak River Impoundment Game Land, continual research and status surveys are needed to determine the present status of each species. *Promenetus exacuous* was thought to be present in North Carolina (Adams 1990), but wasn't confirmed until a few years later (Alderman et al. 1994). Current land management practices, including agriculture and urbanization, are having an effect on the snail fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

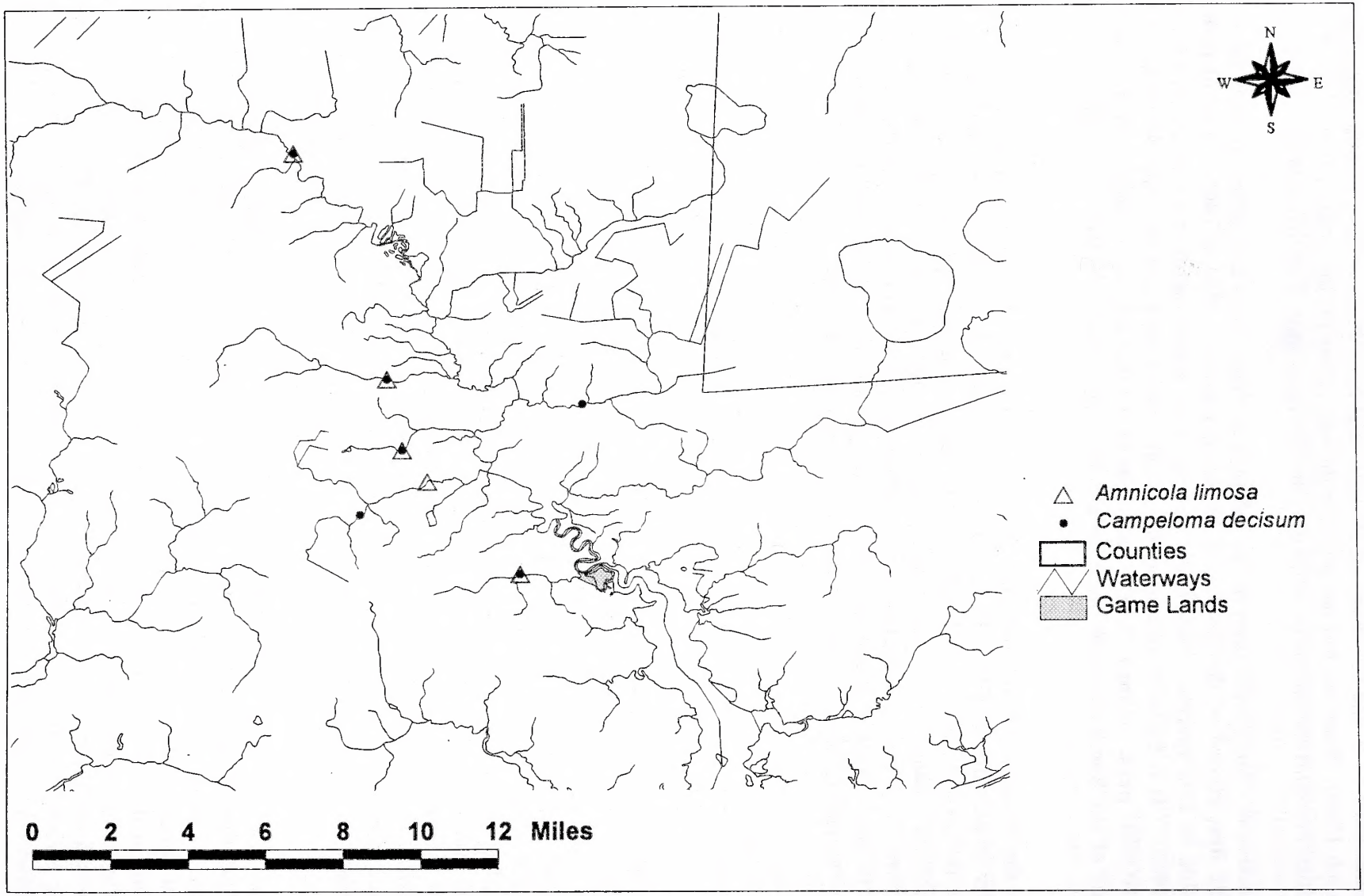

Figure 3a. Map of sites indicating where each species of prosobranch snail was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

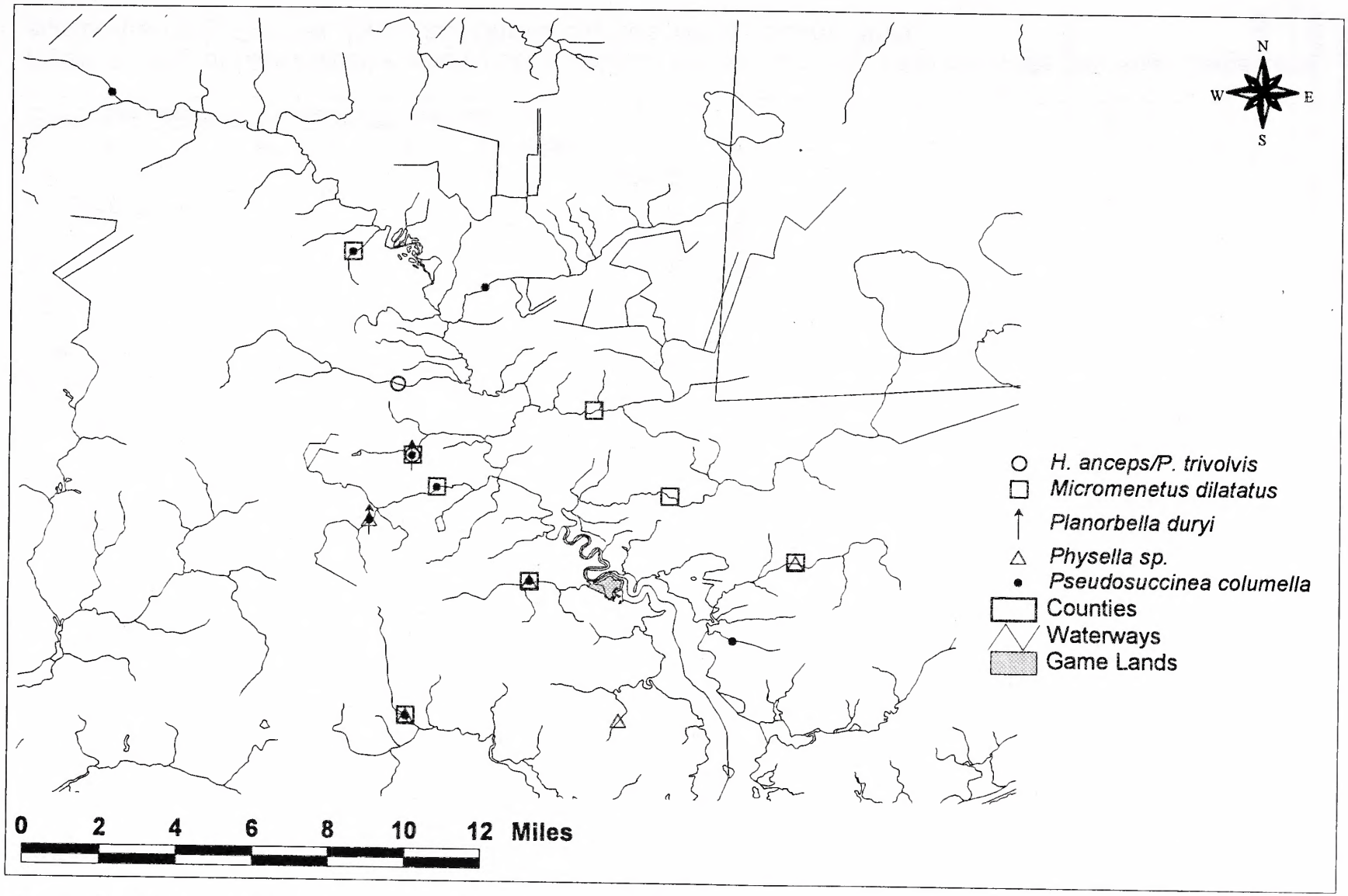

Figure 3b. Map of sites indicating where each species of pulmonate snail was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

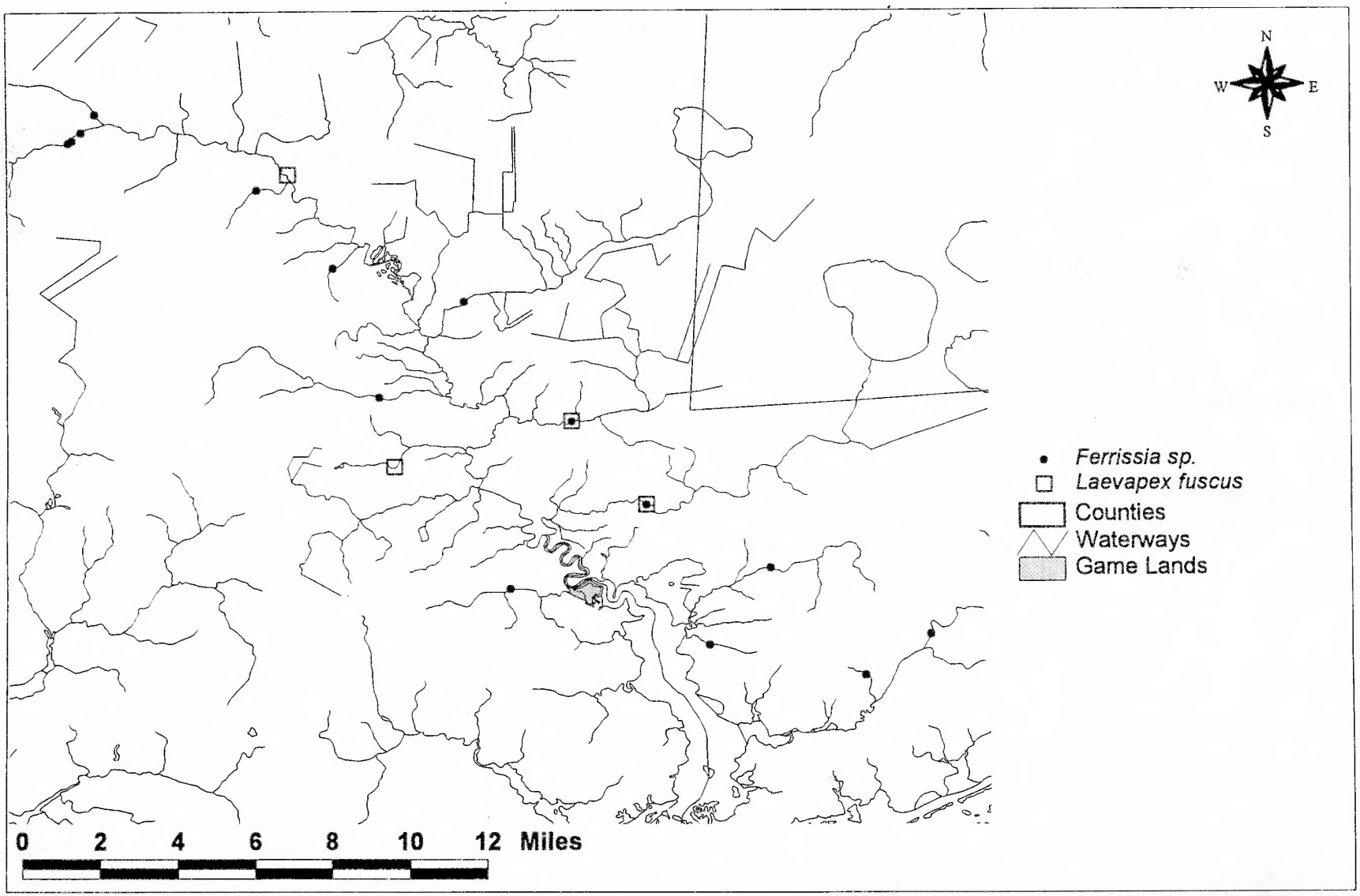

Figure 3c. Map of sites indicating where each species of ancylid was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

Table 3a. Aquatic snail species found in White Oak River Impoundment Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	
Amnicola limosa	mud amnicola
Viviparidae	
Campeloma decisum	pointed campeloma
Pulmonata	
Ancylidae	
Ferrissia sp.	limpet
Laevapex fuscus	dusky ancylid
Lymnaeidae	
Pseudosuccinea columella	mimic lymnaea
Physidae	
Physella sp.	physa snail
Planorbidae	
Helisoma anceps/Planorbella trivolvis	two-ridge/marsh rams-horn
Micromenetus dilatatus	bugle sprite
Planorbella duryi	Seminole rams-horn

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Table 3b. Aquatic snail species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Amnicola limosa							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	patchy uncommon	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	rare	B.T. Watson
Campeloma decisum							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	patchy uncommon	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	abundant	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	common	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	patchy uncommon	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	rare	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	rare	B.T. Watson
***Ferrissia* sp.**							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	patchy common	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000518.2btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 206 -	rare	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	patchy uncommon	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	patchy common	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	patchy uncommon	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	patchy rare	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	patchy rare	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	patchy common	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	uncommon	B.T. Watson
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	patchy rare	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	patchy uncommon	B.T. Watson
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	uncommon	B.T. Watson
001018.3btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	uncommon	B.T. Watson

Table 3b (cont.). Aquatic snail species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Helisoma anceps/Planorbella trivolvis							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	patchy rare	B.T. Watson
Laevapex fuscus							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	common	B.T. Watson, A.E. Bogan
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	patchy common	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	patchy common	B.T. Watson
Micromenetus dilatatus							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	patchy uncommon	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	patchy rare	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	patchy common	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
***Physella* sp.**							
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	uncommon	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	patchy common	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
Planorbella duryi							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	patchy rare	B.T. Watson, A.E. Bogan
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson

Table 3b (cont). Aquatic snail species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Pseudosuccinea columella							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	uncommon	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	rare	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	rare	B.T. Watson

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CRAYFISHES

Aimee H. Fullerton, Nongame Wildlife Biologist
Nongame and Endangered Wildlife Program
Division of Wildlife Management
NC Wildlife Resources Commission

Introduction

Crayfish play important roles in aquatic and sometimes terrestrial ecosystems, both as food sources for many animals and as consumers of plant and animal material. Despite the magnitude of their ecological roles, we have much to learn about crayfish distributions, life histories, and taxonomy. As part of the inventory of aquatic animals associated with the state-owned White Oak River Impoundment Game Land, we conducted field surveys of the crayfishes found in waterways occurring in and around the game land to contribute to our understanding of the distribution and status of crayfishes in North Carolina.

Reproduction and Life History

The crayfishes that occur in North Carolina (all members of the family Cambaridae) live for 2-3 years, on average (Hobbs III 1991, Taylor et al. 1996). Energy obtained from food consumption is allocated largely toward growth as juveniles and toward reproduction as adults (DiStefano 1993). Growth is accomplished through a series of exoskeletal molts (a process known as ecdysis), numbering from 5-10 until adulthood is reached, followed by only 1 (females) or 2 (males) molts per year on average throughout adulthood (Hobbs III 1991, DiStefano 1993). Male cambarid crayfishes exhibit cyclic dimorphism, alternating between a reproductively active form (form I) and a non-reproductive form (form II). Form I males can be present all year, but are usually most abundant during the fall and/or spring. Females carry fertilized eggs attached to their abdomens (a condition that is termed "in berry") for 2-20 weeks, depending on water temperatures. Once hatched, the juveniles are carried on the female until they molt into the 3rd instar (on average), after which they are free-living. Cambarid crayfishes breed more than once during their lives (Hobbs III 1991, DiStefano 1993).

Habitat Requirements and Preferences

Crayfish occur in lentic (e.g., lakes, ponds, marshes, ditches, backwaters of large rivers, groundwater) and lotic (e.g., streams, rivers, groundwater) aquatic habitats ranging from oligotrophic to hypereutrophic (Hobbs III 1991). Crayfish can be further classified as hypogean (below-ground dwellers) or epigean (above-ground dwellers). Hypogean crayfish spend much of their time in elaborate underground burrows associated with groundwater. These burrows can be in close proximity to a water body or stream, but can also be situated far from open water. Depending on the amount of time spent underground and the extent of tunnels created, burrowing crayfish are classified as primary, secondary, or tertiary burrowers (Hobbs III 1991). Generally, epigean crayfish occur in shallow (1-2 m) water, but can occur in deeper water, especially as adults. Juveniles are often found in littoral areas, where adequate shelter provides protection from predation and may mediate competition with adults. Crayfish actively forage at night, but seek shelter from predators during daylight in aquatic macrophytes, leaf litter, woody

debris, overhanging roots, cobble or large boulders, burrows or depressions, and in human debris (e.g., cans, tires) (Lodge and Hill 1994).

Crayfish are affected by both water and habitat quality. Changes in water quality that interfere with respiration (e.g., drastic temperature changes, acidification, pollution) can be detrimental to crayfish populations. Many crayfish are oxygen regulators and can survive changes in oxygen levels (Reiber 1995), but some are oxygen conformers and are less likely to successfully contend with these changes (Hobbs III 1991). Water pollution, caused by sources such as sewage, agricultural and urban runoff, acidification, and auto exhaust, can result in bioaccumulation of pesticides and trace heavy metals (e.g., lead, copper, cadmium). This can harm animals that consume crayfish in addition to directly causing negative effects on crayfish (e.g., mutation, reproductive failure, death) (Taylor et al. 1995, Daveikis and Alikhan 1996, Anderson et al. 1997, Zaranko et al. 1997). Habitat destruction can also negatively affect crayfish populations. Land use practices (e.g., agriculture, logging, development) can alter habitat resulting in fewer areas available as shelter to crayfish (Smith et al. 1996, Richter et al. 1997). For example, siltation and runoff can decrease macrophyte (a source of food and shelter) availability, and channelization can alter stream bed sculpture.

Ecological Interactions

Crayfish are both directly and indirectly linked to the ecosystems in which they live. Because they are omnivorous (i.e., consume both plant and animal food, living or dead), and because they are consumed by animals from various trophic levels, crayfish form multiple links in aquatic and terrestrial food webs (Lodge et al. 1994, Charlebois and Lamberti 1996, Nystrom et al. 1996). Thus, crayfish are involved in the transfer of large amounts of energy in these systems. Crayfish process nutrients and make them available to other animals by (1) breaking down large material via shredding into smaller sizes, and (2) converting nutrients into biomass. Crayfish feed on aquatic vegetation (e.g., macrophytes, algae, periphyton), macroinvertebrates (e.g., aquatic insects, mollusks, small crustaceans), and small vertebrates (e.g., amphibians, small/juvenile fish). Crayfish also consume nonliving organic matter such as leaf litter or terrestrial animal carcasses from the riparian zone or shore and decaying aquatic plant and animal matter (Lodge and Hill 1994). Crayfish in turn are consumed by invertebrates (including other crayfish), fish, amphibians, reptiles, birds, and mammals (Lodge and Hill 1994). Crayfish perform an important role as a member of symbiosis with many invertebrates and as host to various aquatic parasites (Lodge and Hill 1994). Crayfish also experience competition, both between species and among different sizes of individuals within a population (Lodge and Hill 1994).

The introduction of non-indigenous crayfishes to areas currently occupied by native crayfishes can result in competition or even extirpation of natives and can have impacts on other components of the ecosystem (Charlebois and Lamberti 1996, Perry 1998). For example, if crayfish become too abundant, they can be destructive to aquatic ecosystems by destroying more macrophytes than they consume, resulting in less habitat and food for other animals (Lodge et al. 1994, Nystrom et al. 1996). In fact, Lodge et al. (2000) consider nonindigenous crayfish introductions to be the single greatest threat to native crayfish biodiversity worldwide.

Taxonomy, Distribution, and Statuses

In the United States and Canada, approximately 350 taxa of crayfish are recognized (Taylor et al. 1996, J.E. Cooper, NC State Museum of Natural Sciences, Curator of Crustaceans, pers. comm.). However, many species still await description (J.E. Cooper, NCSM, pers. comm.). For example, several current species are now recognized to be species complexes consisting of more than a single taxon. Conversely, animals grouped into several species or subspecies by different authors may actually belong to the same species. The greatest diversity of crayfishes occurs in the Southeast (Hobbs III 1991, Taylor et al. 1996), and North Carolina harbors at least 33 native (possibly up to 46) and 3 introduced species of *Cambarus, Procambarus, Orconectes,* and *Fallicambarus* (Cooper and Braswell 1995, J.E. Cooper, NCSM, pers. comm.). About half of the described crayfishes in North Carolina are of undetermined conservation status due to a lack of data on the distribution and abundance of these animals. Additionally, there are perhaps as many as a dozen native species yet to be described (J.E. Cooper, NCSM, pers. comm.). Of those species for which we have at least some information, the North Carolina Natural Heritage Program lists 10 species as significantly rare (LeGrand and Hall 1998), and the Scientific Council on Freshwater and Terrestrial Crustaceans proposes that 8 of North Carolina's species be of special concern, and that 13 species be put on a watch list (Clamp 1999). New information about current distributions has recently been reported (Cooper and Braswell 1995, Cooper et al. 1998). However, given that undescribed species exist and that we have much to learn about the distributions of crayfishes in North Carolina, it is imperative that we continue to improve our knowledge of crayfish by contributing to the growing database.

Methods

The crayfish survey of White Oak River Impoundment Game Land was conducted during the spring and fall of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and the White Oak River was surveyed via canoe. For clear and tannic shallow streams, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters. For waterways that were mostly swampy, and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Crayfishes were collected using a number of different techniques, depending on the conditions of the waterway being sampled (e.g., substrate type, depth of water). We collected crayfishes by hand or with dip nets from the substrate in which they were hiding (e.g., detritus, leaf packs, root wads, or under rocks). When conditions allowed visual location of crayfish, we corralled individuals into dip nets. We also collected crayfishes by electrofishing. Electrofishing generally proved to be a less successful method than visual location and dip netting, but was effective in shallow, swampy waterways. Collected specimens were preserved and stored in 70% ethanol.

Successful identification of many cambarid crayfishes usually requires collection of reproductive (form I) males. Certain features of their gonopods – the first pair of abdominal appendages, or pleopods – can be important in their taxonomy. Form I males can be distinguished from form II males by the advanced development of the terminal elements at the tips of their gonopods. In

addition, form I males have highly developed hooks on the ischia of certain walking legs (pereiopods) that are used to hold the female during copulation. The size and shape of their chelae may also vary at this stage. Some common characteristics used in identification of non-form I males are carapace length and depth/width ratio, areola width and length, presence and placement of spines, rostrum shape, color, and chela characteristics. Crayfishes were identified by using a taxonomic key (Hobbs Jr. 1991) and a checklist (Hobbs Jr. 1989), by comparing individuals to reference collection specimens (North Carolina Wildlife Resources Commission, and North Carolina State Museum of Natural Sciences), and via personal communication with Dr. J.E. Cooper. Common names are according to Clamp (1999). As our understanding of crayfish taxonomy continues to improve, the identifications of the species we collected may change.

In addition to identifying individuals, we noted approximate abundances of each type of crayfish collected, and quantified average carapace lengths of those collected (from the tip of the rostrum to the posterior carapace edge). We also looked for evidence of recent reproduction and estimated habitat preferences of each species based on the areas from which they were collected. We recorded presence/absence data for each species encountered at each site visited to allow a crude estimate of the distribution of each species within the waterways associated with the game lands. These data will also be added to a larger database describing statewide distributions. Where possible, we recorded notes on ecological interactions (e.g., abundance of food, presence of competitors or predators, quality of habitat). For logistical and ethical reasons, we did not preserve every crayfish collected.

Results

Over 8 days from 10 May to 23 October 2000, 26 sites were inventoried. Crayfish were collected or observed at 23 sites (Figure 4 and Table 4a). Crayfish were not observed at 3 sites. Three species of crayfish were collected during the survey period: *Cambarus (Depressicambarus) latimanus* (LeConte, 1856), *Procambarus (Ortmannicus) acutus* (Girard, 1852), and *Procambarus (Ortmannicus) plumimanus* Hobbs and Walton, 1958. *Palaemonetes paludosus* (freshwater shrimp), *Callinectes sapidus* (blue crab), *Uca minax* (brackish-water fiddler crab), and *Sesarma cinereum* (wharf crab) were also collected during this survey (Table 4a). See Table 4b for statistics on carapace lengths of each species of crayfish collected. These calculations were performed on 1 sample only; we did not record measurements for every individual collected.

Cambarus (D.) latimanus (no common name available) was found at only 1 site and was rare. There was not enough evidence to determine whether reproduction was occurring, and no juveniles were collected. Animals were collected from vegetation and detritus in an area with flow. We found only subadults; this species is a secondary burrower and adults are not often found in open water. The animals collected during this survey exhibited a color pattern characteristic of this species in part of its range: there were parallel rows of dark stripes on the dorsal abdomen; other parts of the carapace were brown and tan with mottling and with hues of pink and salmon; and the fingers of the chelae were tipped in reddish-orange. The coloration is known to differ (stripes lacking and colors and patterns more subtle) in other parts of its range. This species is considered stable and is found throughout a considerable portion of the eastern piedmont and coastal plain of this and other states.

Procambarus (O.) acutus (White River crayfish) was very widespread throughout the survey area, occurring at all but 3 sites. At most sites, the abundance of this species ranged from uncommon to common. Reproduction was evident, as juveniles were present at most sites. Animals were collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. Juveniles were collected more often from shallow areas than were adults. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the piedmont and coastal plain of this and other states.

Procambarus (O.) plumimanus (Croatan crayfish) was found only in the White Oak River at 3 sites. At these sites, 1 adult female and many juveniles were collected from vegetation and detritus in shallow areas along the river edge. The presence of juveniles indicates that reproduction had recently occurred. The coloration of this species was mostly tan with some darker markings and with pastel green and pink or salmon occasionally occurring on the sides of the carapace. This species is small to intermediate in size and is smaller than the other *Procambarus* species collected during this survey. This species is proposed by the Scientific Council of Freshwater and Terrestrial Crustaceans to be placed on a watch list (Clamp 1999).

Palaemonetes paludosus (freshwater shrimp) was collected from 7 sites during this survey. Animals were collected most often from vegetation along stream banks in shallow areas. *Callinectes sapidus* (blue crab) was collected from 3 sites, and *Uca minax* (brackish-water fiddler crab) and *Sesarma cinereum* (wharf crab) were collected from 1 site. Crabs were collected from muddy substrate in shallow areas where salinities were presumably higher than in fresh water. Since the 3 crab species, which are brackish to salt water dwellers, were collected from the game land property, it is unlikely that crayfish reside on the tract of land.

Discussion

The overall diversity of crayfishes in this system was low, possibly because this survey encompassed waterways in only 1 river basin, parts of which had brackish water. Including the 3 crabs and 1 shrimp, the diversity of crustaceans in the system was fair. *Procambarus acutus* was very widespread throughout the surveyed area, but *C. latimanus* and *P. plumimanus* were not, occurring at only 1 and 3 sites, respectively. Both *C. latimanus* and *P. plumimanus* occurred only with *P. acutus*. The methods we used may have overlooked the presence of any burrowing crayfishes, which, if present, would increase the diversity of the system.

Aspects of crayfish communities can tell us something about the system in which they occur. Although we did not directly test water quality, it was clear that the conditions in White Oak River Impoundment Game Land were favorable to support crayfish (at least these species) in most of the freshwater waterways sampled. Current reproduction was evident for *P. acutus* and *P. plumimanus* but we have no information about reproduction of *C. latimanus*. Potential food sources (e.g., allochthonous and autochthonous organic debris, aquatic insects) were available, and vegetation was present. Crayfishes were rarely seen away from cover. Predation pressure on these crayfishes (especially juveniles) was likely moderate because the fish community in this system was fair (see *Fish* section of this report). However, plenty of cover-providing habitat was

available to crayfishes and likely lessened direct impact by predation. It is unclear whether any of the less widespread species was limited by competition or by abiotic factors such as low dissolved oxygen or high acidity.

During our survey, we found 3 of the 5 crayfish species historically known to occur in the White Oak River Basin. Two species that we did not find, but that occur in this river basin, are *Cambarus (Lacunicambarus) diogenes* Girard, 1852 and *Fallicambarus (Creaserinus) fodiens* (Cottle, 1863). Both are burrowing species, and were likely not captured because our survey methods did not adequately address burrowers (we did not dig or trap). Although the majority of our survey was conducted during the spring, when the likelihood of finding a burrowing species in open water is greatest, we did not find any burrowers in open water. In a survey of the Croatan National Forest during 1993-4, 3 of the same species as we collected were observed: *C. latimanus, P. acutus,* and *P. plumimanus* (Alderman et al. 1994). Additionally, they collected *C. diogenes.* This survey has helped to establish the continued presence and further clarify distribution boundaries of several species in the White Oak River Basin.

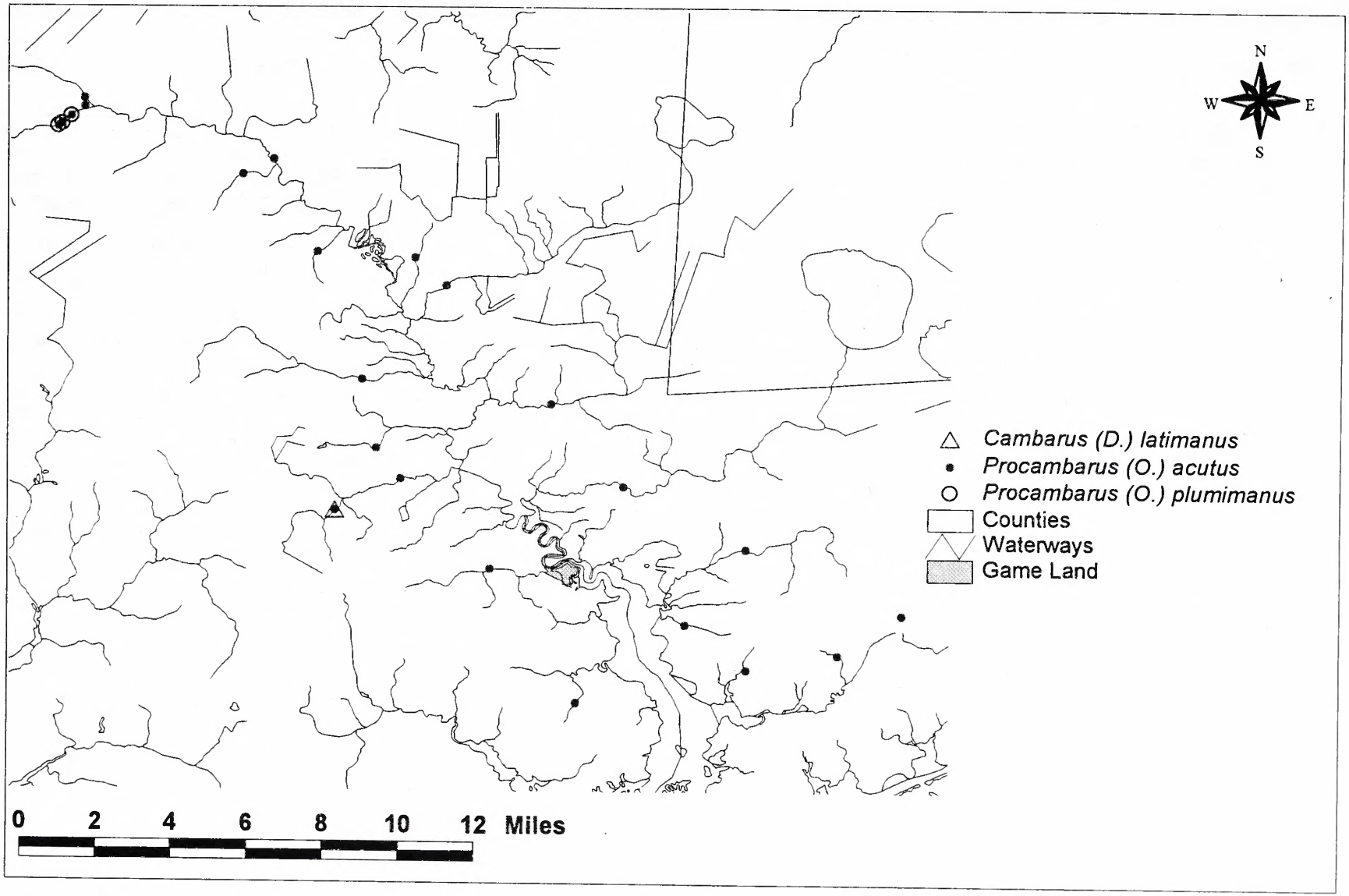

Figure 4. Map of sites indicating where each species of crayfish was collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

Table 4a. Crustaceans found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Cambarus (Depressicambarus) latimanus							
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	A.H. Fullerton
Procambarus (Ortmannicus) acutus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	common	A.H. Fullerton
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	common	A.H. Fullerton
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	common	A.H. Fullerton
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	uncommon	A.H. Fullerton
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	uncommon	A.H. Fullerton
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	common	B.T. Watson
000518.2btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 206 -	present	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	uncommon	B.T. Watson, A.H. Fullerton
000518.4btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek Bay	SR 1109 -/+	uncommon	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	abundant	A.H. Fullerton
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	common	A.H. Fullerton
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	uncommon	A.H. Fullerton
000531.5btw	5/31/2000	White Oak River Game Land	Jones	Tributary to White Oak River	NC 58-	patchy uncommon	A.H. Fullerton
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	common	A.H. Fullerton
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	patchy common	A.H. Fullerton
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	uncommon	A.H. Fullerton
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	rare	A.H. Fullerton
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	present	A.H. Fullerton
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	abundant	A.H. Fullerton
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	patchy common	A.H. Fullerton
001018.3btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	uncommon	A.H. Fullerton
001018.4btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	present	A.H. Fullerton
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	common	A.H. Fullerton
Procambarus (Ortmannicus) plumimanus							
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	common	A.H. Fullerton
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	patchy rare	A.H. Fullerton
001018.3btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117-1118	rare	A.H. Fullerton

Table 4a (cont.). Crustaceans found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Callinectes sapidus							
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	present	B.T. Watson
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	rare	A.H. Fullerton
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	present	A.H. Fullerton
Sesarma cinereum							
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	present	A.H. Fullerton
Uca minax							
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	common	A.H. Fullerton
Palaemonetes paludosus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	abundant	A.H. Fullerton
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	A.H. Fullerton
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	uncommon	A.H. Fullerton
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	common	A.H. Fullerton
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	common	A.H. Fullerton
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	abundant	A.H. Fullerton
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	present	A.H. Fullerton

Prob. P. pugio based on presence of Uca, Sesarma + Callinectes @ same site

Table 4b. Statistics on carapace lengths (mm) of crayfishes found in White Oak River Impoundment Game Land and associated waterways. See text for common names.

Procambarus (Ortmannicus) acutus	Avg	Std	Min	Max
female (6 records)	23.3	18.4	8.0	48.0
male II (16 records)	14.8	5.4	7.5	24.0
Species Total (22 records)	17.1	10.8	7.5	48.0

Procambarus (Ortmannicus) plumimanus	Avg	Std	Min	Max
female (5 records)	17.4	7.9	13.5	31.5
male II (9 records)	13.9	3.2	7.0	17.5
Species Total (14 records)	15.2	5.3	7.0	31.5

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FRESHWATER FISHES

Brian T. Watson, Nongame Wildlife Biologist
Nongame and Endangered Wildlife Program
Division of Wildlife Management
NC Wildlife Resources Commission

Introduction

Fishes are the most numerous and diverse of the major vertebrate groups. Their various morphological, behavioral, reproductive, and physiological adaptations have allowed them to dominate the waters of the world. Fishes can be found in a broad array of habitats, including vernal pools, mountain streams, and the ocean floor. Their dominance is reflected in the number of living species. Over 24,600 species have been described (Moyle and Cech 1996), and it is believed that this number may increase to approximately 28,500 (Nelson 1994). The North American continent harbors approximately 1,100 species of freshwater fish (Burr and Mayden 1992), with 790 (75%) species occurring in the United States (Page and Burr 1991). Nearly 200 native species can be found in North Carolina (Menhinick 1991).

While most of the attention from the public and fisheries biologists is directed towards the game fishes, these species make up only about 5% of the freshwater fish fauna in the United States. The remaining 95% are little known, but charismatic, nongame species, such as darters and minnows. Nongame fishes play a vital role in the balance of aquatic ecosystems. Their diets are diverse, and, in turn, they serve as dietary components for sport fishes, water birds, and other wildlife. They also are important indicators of water quality and can signal when aquatic ecosystems are being negatively impacted. Game fishes also are important components of aquatic ecosystems and provide a source of recreation and employment for many people. Unfortunately, in 1989, the American Fisheries Society regarded 364 North American freshwater fish species as endangered, threatened, or special concern, an increase of 45% in just 10 years (Williams et al. 1989). This number represents approximately one-third of the North American native freshwater fish fauna. Likewise, the southern United States, which supports more native fishes than any comparable size on the North American continent north of Mexico, has experienced a 75% increase in jeopardized fishes since 1989 and a 125% increase in 20 years (Warren et al. 2000). In North Carolina, approximately 25% of the freshwater fishes are state listed. Some of the reasons for this decline include habitat alteration and loss, chemical pollution, overexploitation, and introduction of exotic species. Given this information, it is essential that we better understand the taxonomy, distribution, and conservation needs of the various taxa. Therefore, a freshwater fish inventory of the waterways in and around the state-owned White Oak River Impoundment Game Land was initiated to ascertain some of this needed information.

Methods

The freshwater fish survey of White Oak River Impoundment Game Land was conducted during the spring and fall of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and the White Oak River

was surveyed via canoe. For clear and tannic shallow streams, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters. For waterways that were mostly swampy, and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater fishes were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). One of the more common methods used was backpack electrofishing (13 of 26 sites). This method was chosen because it is more comprehensive and efficient than other methods used to collect fishes in streams. It is typically used more often in our surveys, but conductivity and water levels did not always render electrofishing as a viable option. The other commonly used technique incorporated into the survey included the use of dip nets. Most fishes collected were identified to species and released unharmed. However, it was necessary to perform some of the identifications in the laboratory. These identifications were carried out by fixing the fish in 10% formalin and preserving them in 70% ethanol. Once the fishes were preserved, they were identified with the use of a compound microscope (Nikon). Fishes were identified according to Menhinick (1991), Page and Burr (1991), Rhode et al. (1994), and Jenkins and Burkhead (1994). Dr. Wayne C. Starnes and others (G.M. Hogue, T.L. Fullbright, and Dr. M.E. Raney) from the NC State Museum of Natural Sciences verified some of the identifications. Besides presence-absence data, relative abundance and recent reproduction information were noted for each species to determine population health.

Results

Over 8 days from 10 May to 23 October 2000, 25 sites were inventoried (site 4 was surveyed primarily for mussels) and fishes were collected or observed at 23 localities (Figure 5). Twenty-four species representing 13 families were documented during the survey of White Oak River Impoundment Game Land (Tables 5a and 5b). Of the approximately 70 species that have been documented in the White Oak River Basin (Menhinick 1991), we confirmed the presence of only 23 of these species. Limitations as to our access to all available habitats and sampling range within the river basin were the most likely reasons for the absence of many species. For example, a fair number of the species were documented near the coast, in the New River Subbasin, or eastern Carteret County (Menhinick 1991), while we only surveyed the White Oak River and its tributaries. In addition, we didn't intensively survey the White Oak River, which a number of species were shown to inhabit much more frequently than other waterways (Menhinick 1991). Elimination of these species would result in the collection of over 50% of the documented fish species from the area. While we did not document the presence of any new species to the White Oak River Basin, *Lagodon rhomboides* was collected at 1 site, a tributary to the White Oak River. Menhinick (1991) comments on this species as being abundant from Pamlico Sound south, seldom entering fresh water. Overall, abundance, distribution, and recent reproduction were low for most species encountered. Survey effort, due to site conditions, made it difficult to assign accurate relative values at many localities.

Since not all specimens were preserved for laboratory or museum identification, we have chosen to classify some records to genus only. In a number of instances, this was necessary since some specimens were only seen while electrofishing and species identification was impractical.

Discussion

The waterways associated with White Oak River Impoundment Game Land contain a relatively low diversity and distribution of fish species. While a few of the fish species were collected at a wide range of locations (e.g., *Enneacanthus gloriosus* and *Gambusia holbrookii*), the majority of species tended to occur over a restricted area. Species abundance was typically low at many sites, with no one species comprising a majority of the biomass. The low distribution and abundance of a majority of the species were likely significantly aided by the lack of intensive survey techniques. A number of sites had characteristics that made them virtually impossible to backpack electrofish, while even some of the sites we electrofished were difficult due to the apparently high conductivities. Therefore, dip netting became a significant, but less than desired, technique during the survey. Overall, the area we surveyed was mostly rural and undeveloped, resulting in minimal urbanization effects with some agricultural impacts, which may tend to reflect different results than those reported here. Unfortunately, we do not have any recent survey results for comparison to obtain an accurate reflection of the species composition and distribution of the area.

While no threatened or endangered fish species was collected during the survey of White Oak River Impoundment Game Land, continual research and status surveys are needed to determine the present status of each species. Current land management practices, including agriculture and urbanization, are having an effect on the fish fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

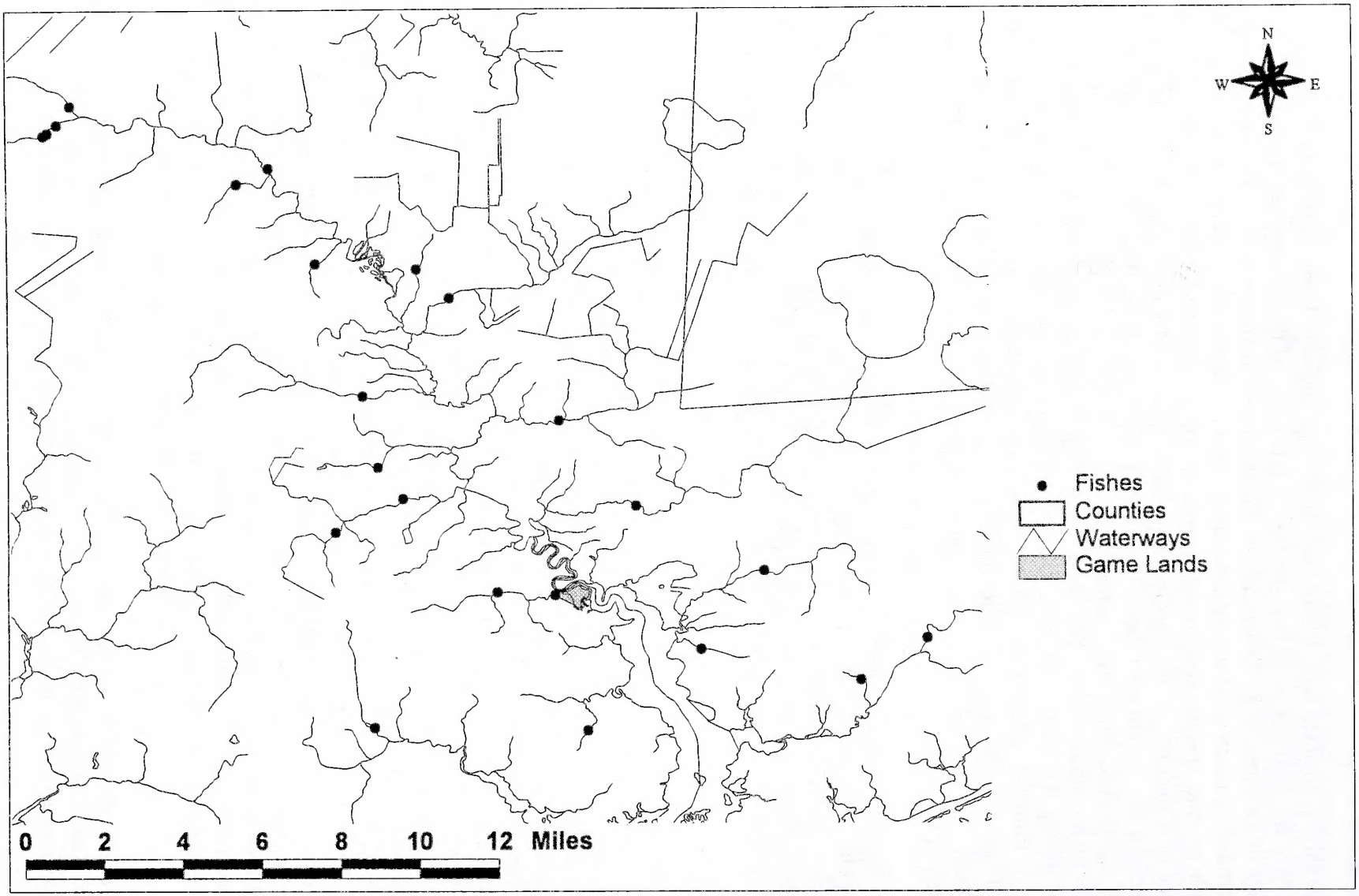

Figure 5. Map of sites indicating where fishes were collected in the White Oak River Game Land aquatic inventory, Carteret, Jones, and Onslow counties, North Carolina, 2000.

Table 5a. Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Amblyopsidae	
Chologaster cornuta	swampfish
Anguillidae	
Anguilla rostrata	american eel
Aphredoderidae	
Aphredoderus sayanus	pirate perch
Catostomidae	
Erimyzon oblongus	creek chubsucker
Centrarchidae	
Acantharchus pomotis	mud sunfish
Centrarchus macropterus	flier
Chaenobryttus gulosus	warmouth
Enneacanthus gloriosus	bluespotted sunfish
Lepomis auritus	redbreast sunfish
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus	bluegill
Micropterus salmoides	largemouth bass
Cyprinidae	
Notemigonus crysoleucas	golden shiner
Notropis chalybaeus	ironcolor shiner
Cyprinodontidae	
Cyprinodon variegatus	sheepshead minnow
Esocidae	
Esox americanus	redfin pickerel
Ictaluridae	
Ameiurus natalis	yellow bullhead
Noturus gyrinus	tadpole madtom
Noturus insignis	margined madtom
Percidae	
Etheostoma olmstedi	tesselated darter
Etheostoma serrifer	sawcheek darter
Poeciliidae	
Gambusia holbrookii	eastern mosquitofish
Sparidae	
Lagodon rhomboides	pinfish
Umbridae	
Umbra pygmaea	eastern mudminnow

Table 5b. Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Acantharchus pomotis							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	rare	B.T. Watson
000531.5btw	5/31/2000	White Oak River Game Land	Jones	Tributary to White Oak River	NC 58-	rare	B.T. Watson
Ameiurus natalis							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
001018.3btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
***Ameiurus* sp.**							
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
Anguilla rostrata							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	common	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	common	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	uncommon	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	common	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	common	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	common	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson

Table 5b (cont.). Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Aphredoderus sayanus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	common	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	uncommon	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	uncommon	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	uncommon	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	common	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	abundant	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	abundant	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	present	B.T. Watson
000531.5btw	5/31/2000	White Oak River Game Land	Jones	Tributary to White Oak River	NC 58-	common	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	common	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	common	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	uncommon	B.T. Watson
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	common	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	common	B.T. Watson
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	common	B.T. Watson
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	uncommon	B.T. Watson
001018.3btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	common	B.T. Watson
Centrarchus macropterus							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	rare	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	rare	B.T. Watson
000531.5btw	5/31/2000	White Oak River Game Land	Jones	Tributary to White Oak River	NC 58-	rare	B.T. Watson
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
Chaenobryttus gulosus							
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson

Table 5b (cont.). Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Chologaster cornuta							
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	uncommon	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	present	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	present	B.T. Watson
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson
Cyprinodon variegatus							
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	present	B.T. Watson
Enneacanthus gloriosus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	common	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	uncommon	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	uncommon	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	rare	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	present	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	present	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	present	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	common	B.T. Watson
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	common	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson
Erimyzon oblongus							
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson

Table 5b (cont.). Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Esox americanus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	rare	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	common	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	common	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	common	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	present	B.T. Watson
000531.5btw	5/31/2000	White Oak River Game Land	Jones	Tributary to White Oak River	NC 58-	abundant	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	common	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	uncommon	B.T. Watson
***Esox* sp.**							
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson
Etheostoma olmstedi							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
Etheostoma serrifer							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	common	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	present	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	present	B.T. Watson
000601.1btw	6/1/2000	White Oak River Game Land	Jones	Holston Creek	NC 58	present	B.T. Watson
001018.1btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
001018.2btw	10/18/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1117 to SR 1118	present	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson

Table 5b (cont.). Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
***Etheostoma* sp.**							
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	rare	B.T. Watson
Gambusia holbrookii							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.2btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1434/Bike 3-	uncommon	B.T. Watson
000511.3btw	5/11/2000	White Oak River Game Land	Onslow	Grants Creek	SR 1428-	uncommon	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	uncommon	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	common	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	common	B.T. Watson
000518.2btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 206 -	present	B.T. Watson
000518.3btw	5/18/2000	White Oak River Game Land	Carteret	Tributary to Pettiford Creek	FR 128 -	uncommon	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	common	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	uncommon	B.T. Watson
000531.6btw	5/31/2000	White Oak River Game Land	Jones	Black Swamp Creek	NC 58	common	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	common	B.T. Watson
001017.1btw	10/17/2000	White Oak River Game Land	Onslow	White Oak River Impoundment	Game Land	present	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	common	B.T. Watson
Lagodon rhomboides							
000601.3btw	6/1/2000	White Oak River Game Land	Carteret	Tributary to White Oak River	SR 1106	present	B.T. Watson, W.C. Starnes
Lepomis auritus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
Lepomis gibbosus							
000511.1btw	5/11/2000	White Oak River Game Land	Onslow	Mulberry Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	abundant	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	present	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson

Table 5b (cont.). Freshwater fish species found in White Oak River Impoundment Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Lepomis macrochirus							
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	abundant	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	present	B.T. Watson
Micropterus salmoides							
000511.4btw	5/11/2000	White Oak River Game Land	Onslow	Queen Creek	SR 1744 -	rare	B.T. Watson
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson
Notemigonus crysoleucas							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000518.1btw	5/18/2000	White Oak River Game Land	Onslow	Tributary to Holland Mill Creek	SR 1444-	rare	B.T. Watson
Notropis chalybaeus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson, W.C. Starnes
000601.4btw	6/1/2000	White Oak River Game Land	Carteret	Hadnot Creek	SR 1104-	rare	B.T. Watson, W.C. Starnes
***Notropis* sp.**							
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	present	B.T. Watson
Noturus gyrinus							
000510.5btw	5/10/2000	White Oak River Game Land	Onslow	Starkys Creek	SR 1434/Bike 3 -	rare	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson
Noturus insignis							
000601.2btw	6/1/2000	White Oak River Game Land	Jones/Carteret	Hunters Creek	SR 1100/1103-	rare	B.T. Watson
001023.1btw	10/23/2000	White Oak River Game Land	Onslow/Jones	White Oak River	SR 1118-	present	B.T. Watson
Umbra pygmaea							
000511.5btw	5/11/2000	White Oak River Game Land	Onslow	Webb Creek	SR 1434/Bike 3	rare	B.T. Watson
000531.1btw	5/31/2000	White Oak River Game Land	Jones	Great Creek	SR 1116-	present	B.T. Watson
000531.2btw	5/31/2000	White Oak River Game Land	Onslow	Gibson Branch	SR 1331-	present	B.T. Watson
000531.4btw	5/31/2000	White Oak River Game Land	Onslow	Tributary to White Oak River	SR 1331-	common	B.T. Watson

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